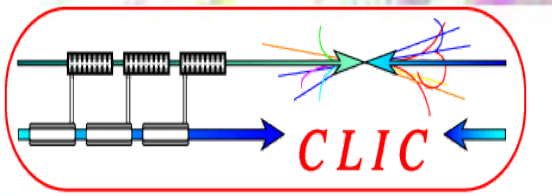


Z' Scans at CLIC

Orhan Cakir
Ankara University

M. Battaglia (CERN/LBNL), I.Turk Cakir (TAEA)

CLIC'09 Workshop, CERN, 12-16 October 2009

Outline

- Introduction – Z' boson
- Z' models
- Z' line shape at CLIC
- ISR and BS effects
- Sensitivity to parameters
- Conclusions

Z' Boson

- The Z' boson is a new particle predicted in many extensions of the standard model. It is massive, electrically-neutral and color-singlet particle of spin-1. The LEP and Tevatron data constrain many Z' models[*]. Assuming the couplings of order 0.1, the LHC experiments will probe Z' mass up to 4-5 TeV depending on the specific model.

*Experimental bounds (95% CL.) on Z' boson mass for different models**

	χ	ψ	η	LR	SSM
CDF	>822 GeV	>822 GeV	>891 GeV	>630 GeV	>923 GeV
LEP	>781 GeV	>475 GeV	>515 GeV	>600 GeV	>1305 GeV
Electroweak analysis	---	---	>619 GeV	>860 GeV	>1500 GeV

[*]C. Amsler *et al*, Review of Particle Physics, PDG08, PLB667, 1 (2008)

Why CLIC energies?

- Current experimental limits on Z' boson mass favors higher energy (≥ 1 TeV).
- Interest on Z'-line shape, ISR and BS effects, precision measurements.
- If a Z' boson can be found at LHC, the underlying model could be best identified at CLIC measuring its line-shape and couplings.
- CLIC has more potential to explore Z' boson by exploiting beam polarization and asymmetries in the cross section.

Z' Models

- Additional U(1) current in E_6 model,

$$J^{f}_{Z'\mu} = J^{f}_{\chi\mu}\cos\theta_6 + J^{f}_{\psi\mu}\sin\theta_6$$

$$\theta_6 = 0 \rightarrow \chi$$
$$\theta_6 = \pi/2 \rightarrow \psi$$
$$\theta_6 = -\tan^{-1}\sqrt{5/3} \rightarrow \eta$$

- Additional $U(1)_{B-L}$ symmetry leads to B-L model: Z' couples to the current

$$J_{Z'\mu} = \alpha_{LR} J_{3R\mu} - 1/(2\alpha_{LR}) J_{(B-L)\mu}$$

$$\alpha_{LR} = \sqrt{g_R^2/g_L^2 \cot^2\theta_w - 1}$$

- Sequential model (S): ==> Same coupling as the SM Z-boson

Phenomenologically, Z' boson - fermion interaction

$$J^{f}_{Z'\mu} = \bar{f}\gamma_\mu[V'_f + \gamma_5 A'_f]f$$

Z' Couplings

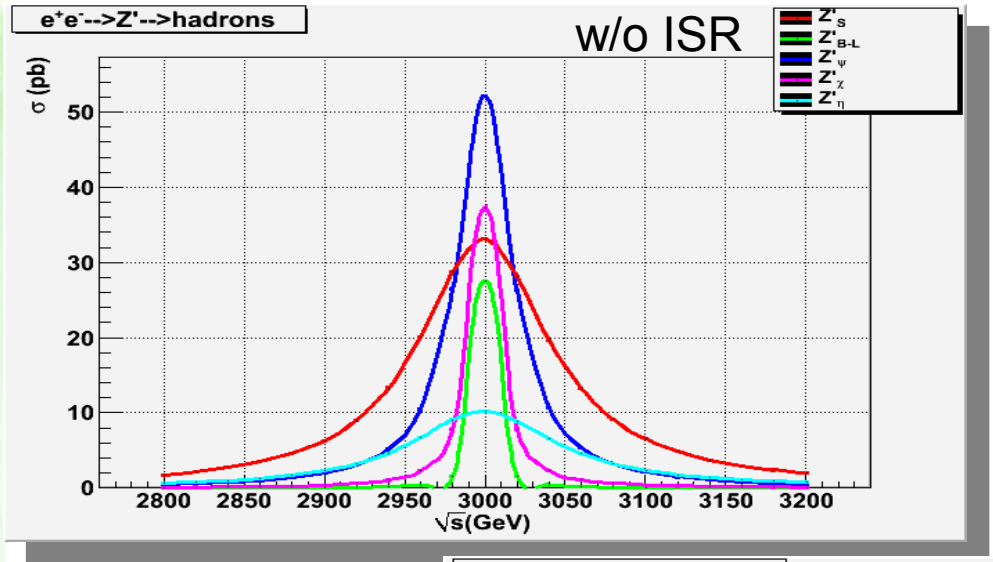
	up-quark		down-quark		charged-lepton		neutrino	
Models	V'_u	A'_u	V'_d	A'_d	V'_e	A'_e	V'_ν	A'_ν
Z'_S	-0.6933	-1	0.3867	1	-0.0800	-1	1	1
Z'_{B-L}	0.1868	0	0.1868	0	-0.5608	0	-0.2804	-0.2804
Z'_ψ	0	0.5055	0	0.5055	0	0.5055	0.2527	0.2527
Z'_χ	0.7832	-0.3916	0	0.7832	-0.7832	-0.3916	-0.5873	-0.5873
Z'_η	0.4796	0.1599	0	1.9183	-0.4796	0.1599	-0.1599	-0.1599

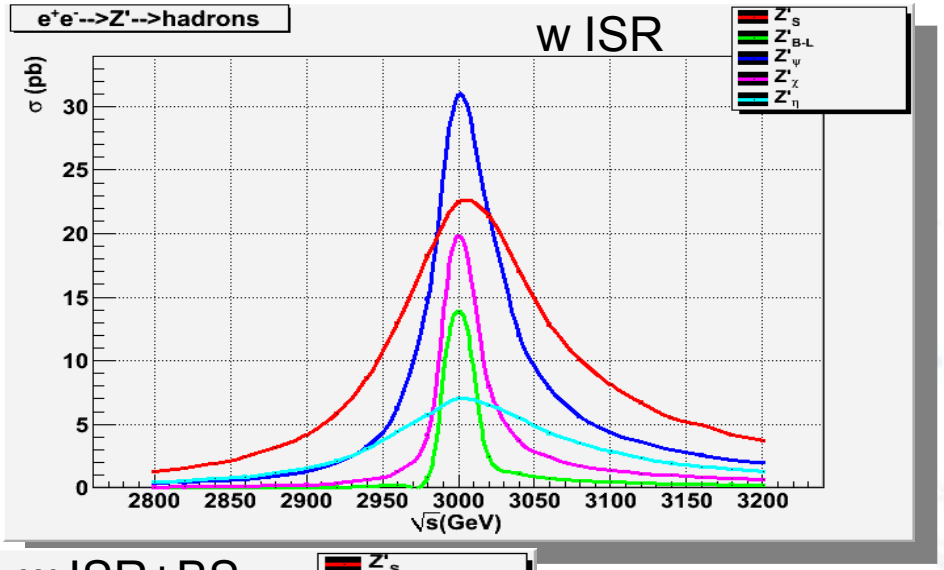
Models	Z'_S	Z'_{B-L}	Z'_ψ	Z'_χ	Z'_η
Width(GeV) for $m_{Z'}$=3 TeV	98.2	9.8	20.6	40.4	108.9

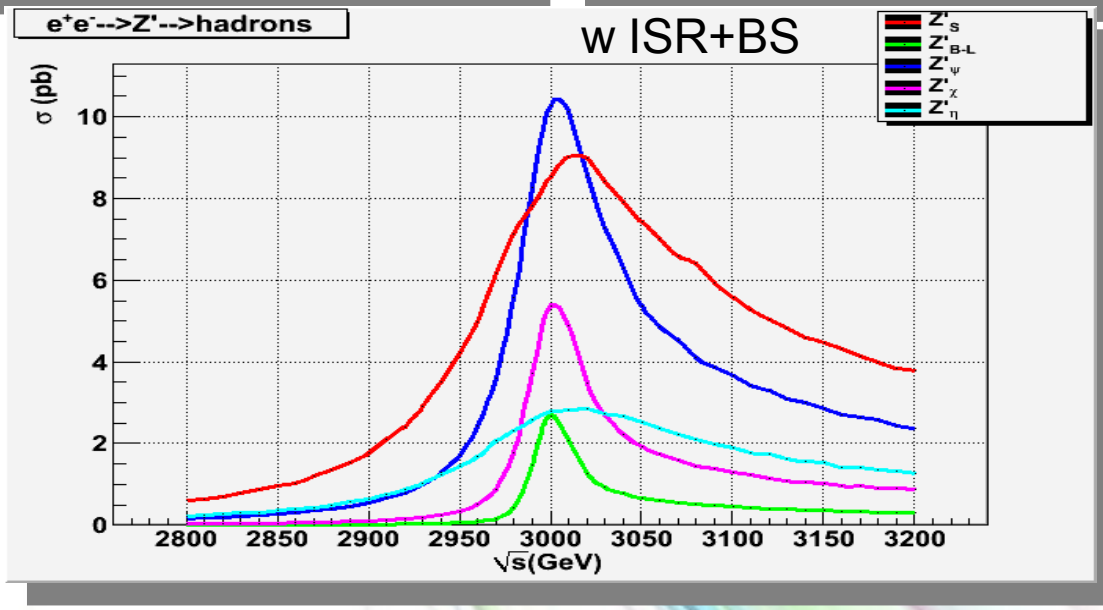
We performed our analysis with the help of PYTHIA 6.421 program. Beamstrahlung effects are studied by using CALYPSO library for the CLIC luminosity/energy spectrum provided by D. Schulte,

http://dschulte.web.cern.ch/dschulte/physics/calypso/CLIC_3TeV_001/lumi.ep.gz

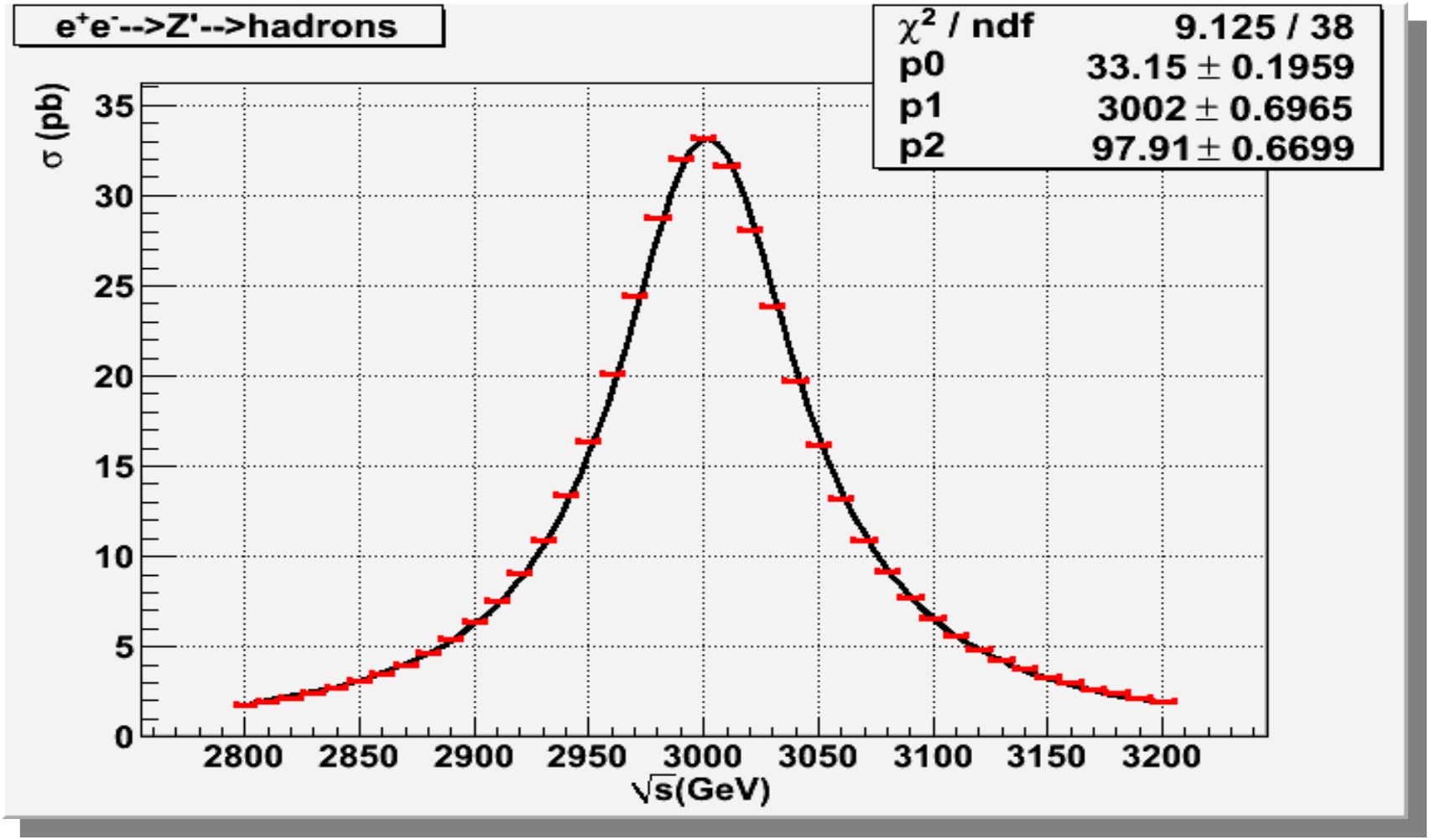
Different Z' models and the cross sections w/o and w ISR+BS effects at CLIC







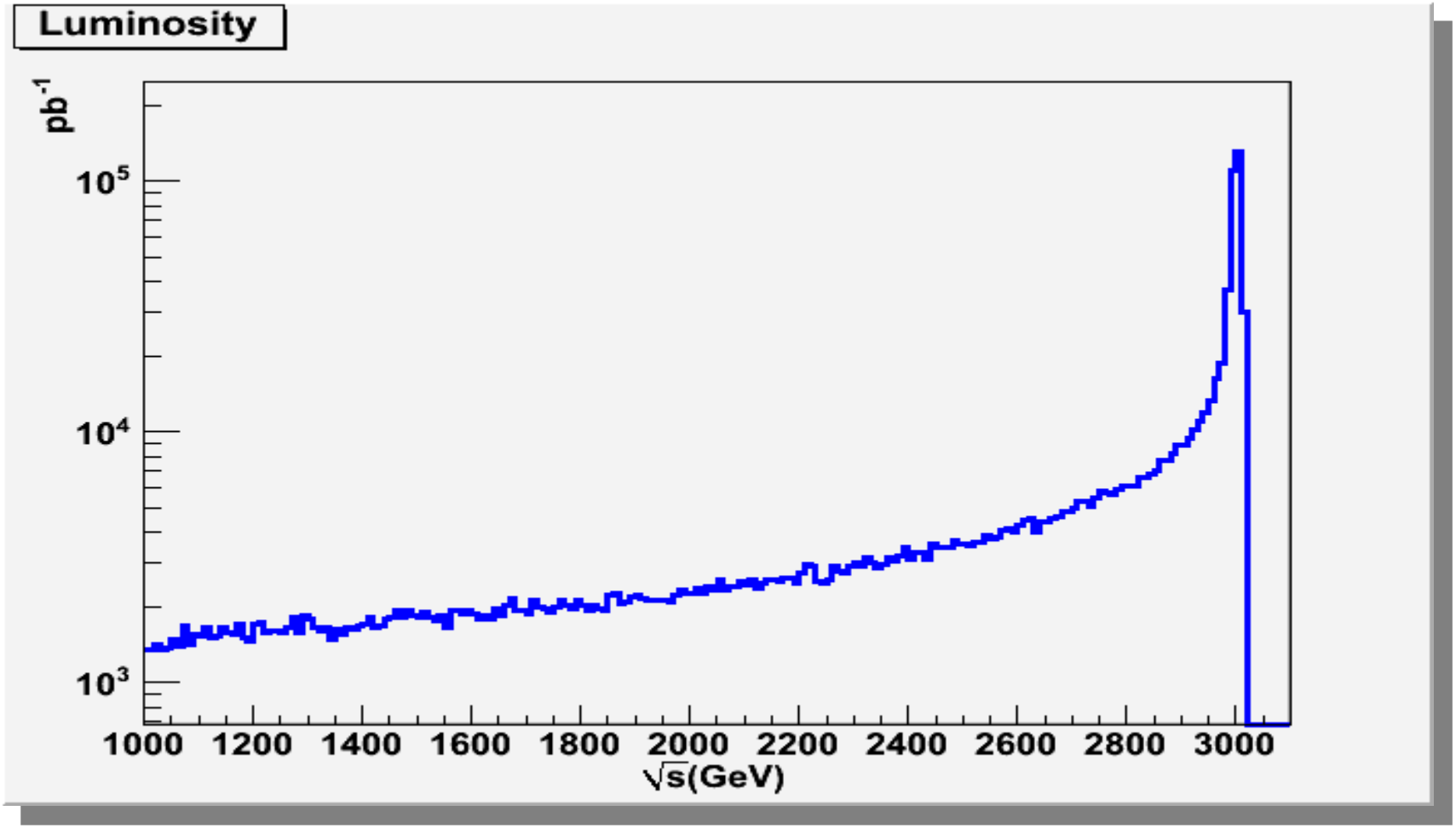
Z'_S Model: Distribution w/o ISR



Breit-Wigner shape of the Born cross section having maximum σ=33 pb at $\sqrt{s}$=3000 GeV for $m_{Z'}$=3000 GeV.

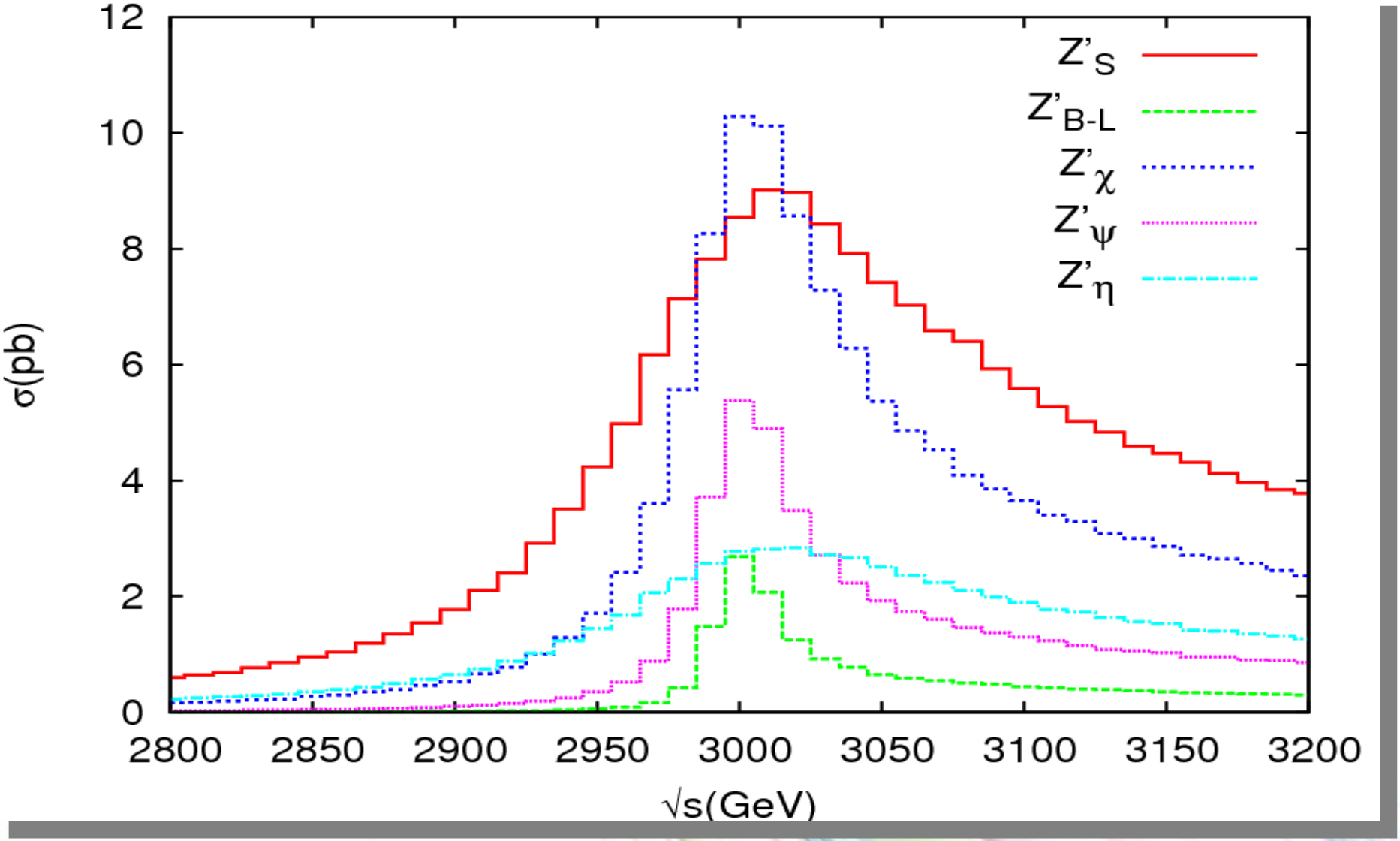
Energy/Luminosity Spectrum

- CLIC luminosity spectrum at/around 3 TeV

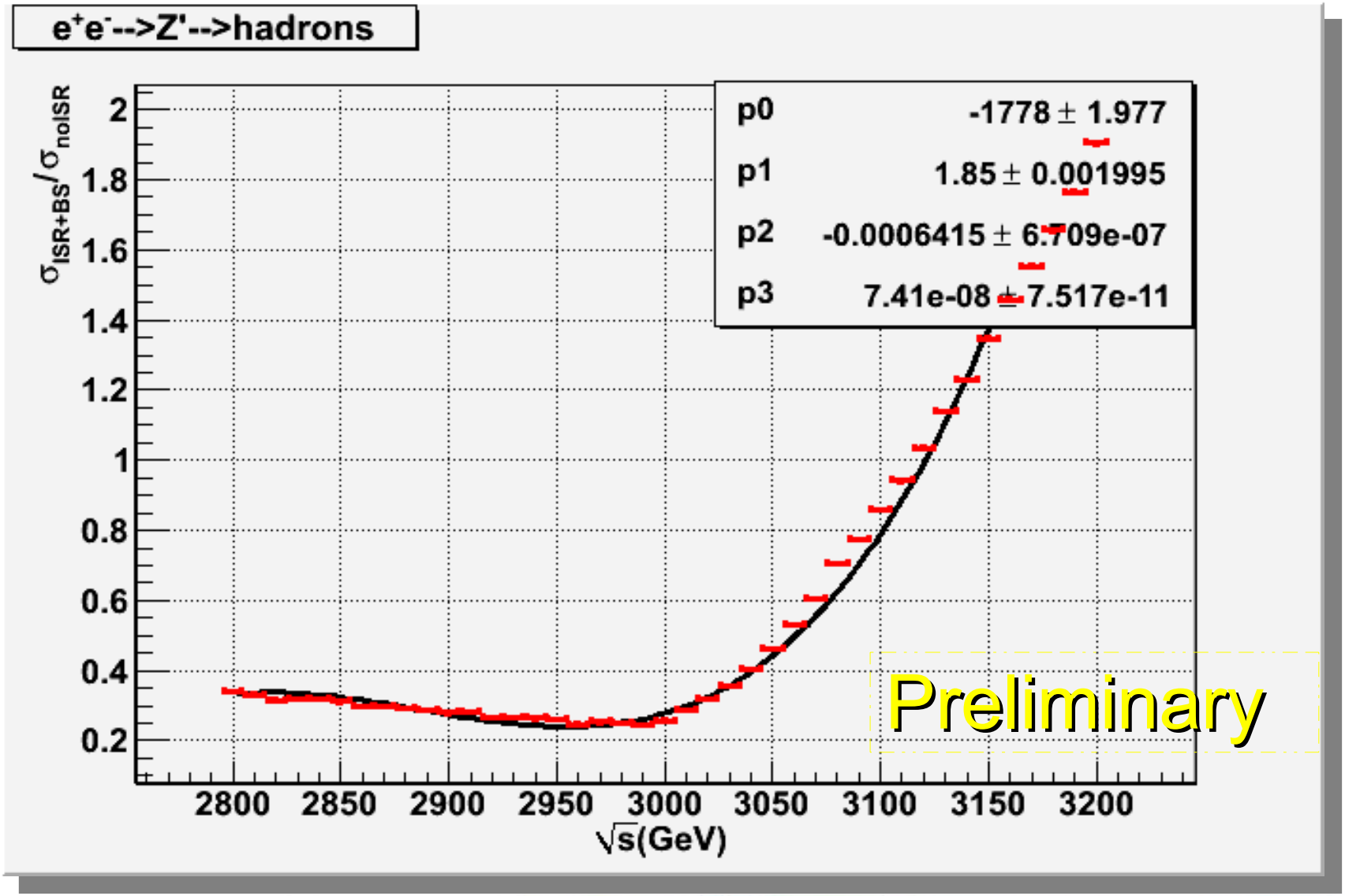


http://dschulte.web.cern.ch/dschulte/physics/calypso/CLIC_3TeV_001/lumi.ep.gz

e^+e^--->Z'-->hadrons with ISR+BS effects



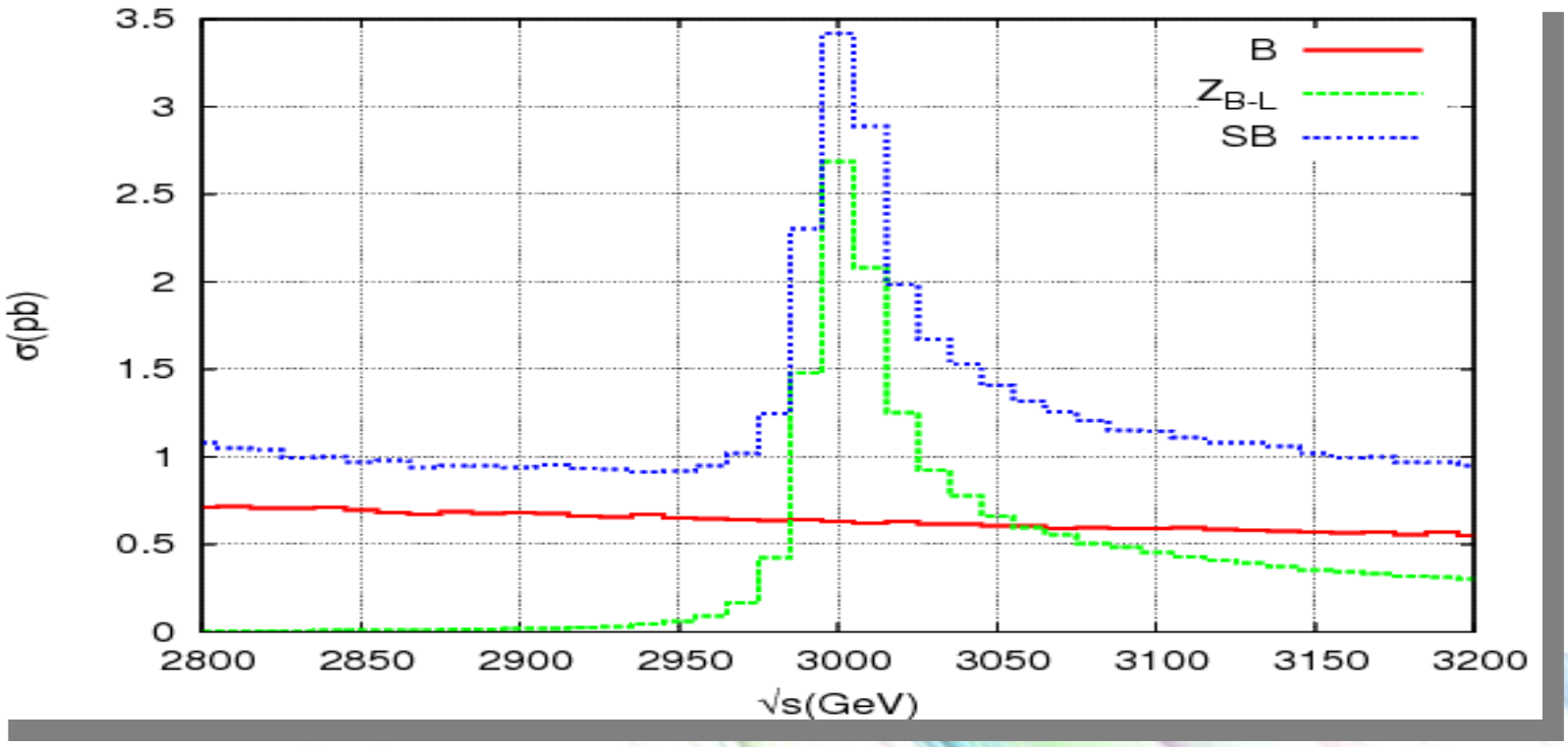
Z'_S Model: the ratio ($\sigma_{ISR+BS}/\sigma_{noISR}$)



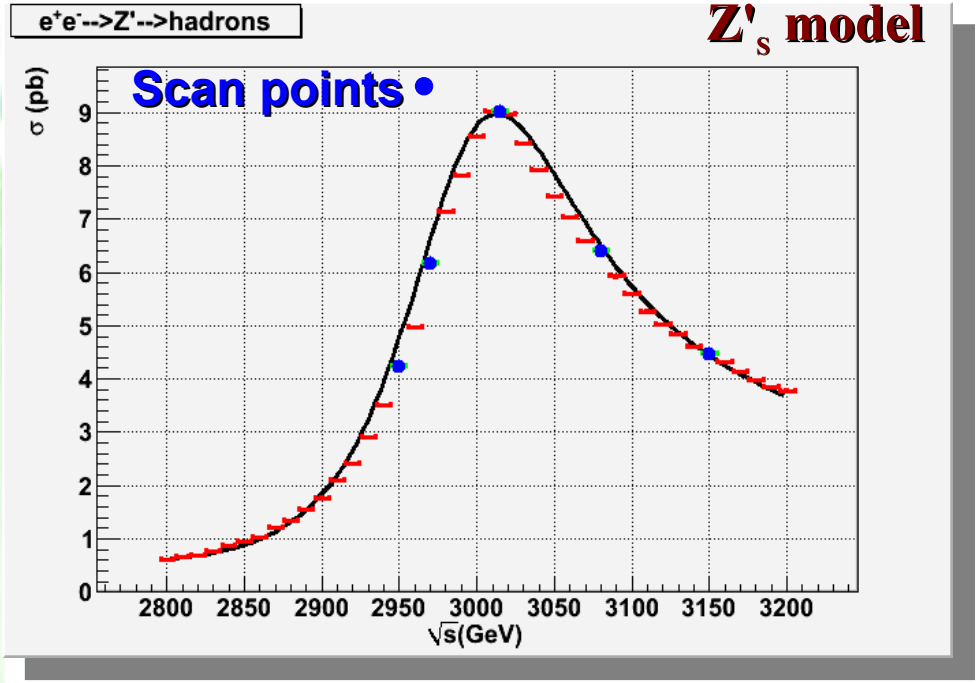
Background (B) and Interference (SB) with ISR+BS effects

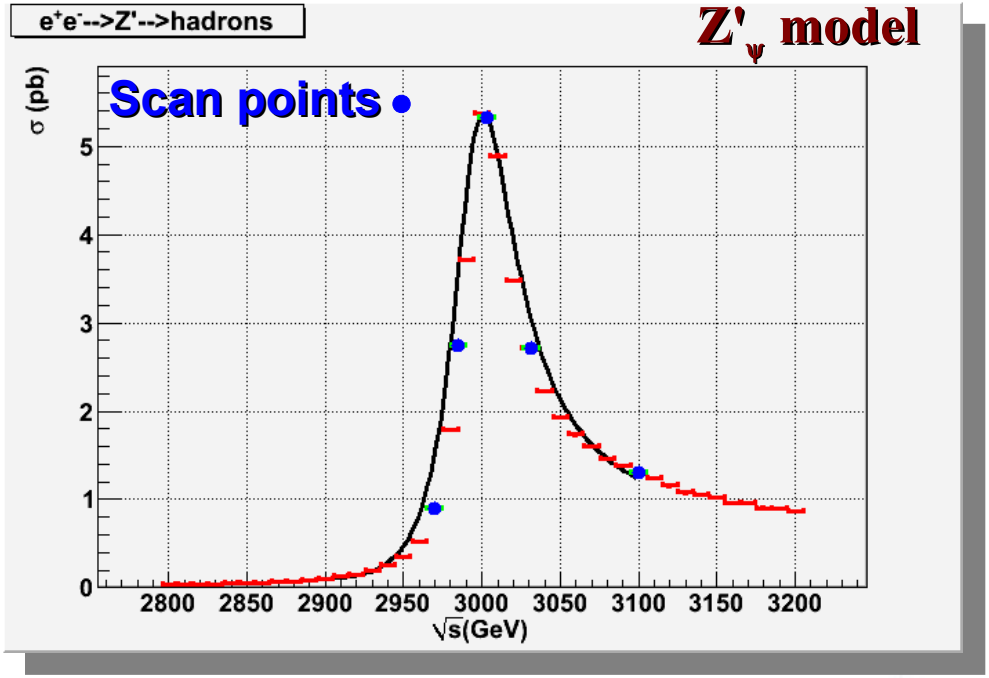
- Physics background (e^+e^- -->$q\ \bar{q}$)

Model	σ_S(pb)	σ_B(pb)	σ_{SB}(pb)
Z'_S	8.5468	0.6286	8.6568
Z'_{B-L}	2.6842	0.6286	3.4147



Scan Points and Ranges





The scan could be performed for the models in the ranges:

Z'_S: 2950-3150 GeV

Z'_ψ: 2970-3100 GeV

Z'_χ: 2980-3070 GeV

Z'_η: 2950-3150 GeV

Z'_{B-L}: 2980-3050 GeV

Scans of 2% downward and 5% upward energy are needed to cover all the Z' models. The 5% changes in the energy will lead to 10-15% loss in luminosity. This translates to a scan time of a factor 1.2 compared to that of the nominal energy. A data set of 1 ab^{-1} is assumed for the CLIC 3 TeV, and it is shared in a five point scan.

Results

We find the fit function for the Z' production cross section with beamstrahlung and ISR effects as

$$F(\sqrt{s}; m, \Gamma, \sigma_0)$$

the BW function is in the form,

$$f_{BW}(\sqrt{s}; m, \Gamma, \sigma_0) = \frac{\sigma_0 \cdot \Gamma^2/4}{\left[(\sqrt{s}-m)^2 + \Gamma^2/4\right]}$$

and the function for ISR and BS smears the cross section as well as the width. As a result, due to the ISR+BS effects the cross section peak shifts to about 3010 GeV, and Z' width widens.

From the χ^2 fit we find the parameters, and Z'-line shape parameters can be measured at CLIC 3 TeV with a precision

$$\Delta\sigma_0 \simeq 0.1\, pb, \Delta\Gamma \simeq 0.7\, GeV, \Delta m \simeq 0.7\, GeV$$

Conclusion

- e^+e^--->Z'-->hadrons events are generated for $m_{Z'}$=3 TeV, including ISR and BS (with the luminosity spectrum) by using PYTHIA 6.4.
- A data of 1 ab^{-1} is assumed for the CLIC at 3 TeV, this is shared in 5 points scan: mass, width and peak value of cross section are obtained from a χ^2 fit.
- Z'-->hadrons channel is important to probe various combinations of the couplings. The results can be combined for both leptonic and hadronic final states to provide the necessary accuracies for the couplings.

Backup Slides

Z'_S and Z'_ψ models: Fit to scan region with ISR+BS effects